

Use and complications of operative control of arterial inflow in combat casualties with traumatic lower-extremity amputations caused by improvised explosive devices

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BACKGROUND:	Proximal traumatic lower-extremity amputation has become the signature injury of the war in Afghanistan. Casualties present in extremis and often require immediate operative control of arterial inflow to prevent exsanguination. This study evaluated the use of this strategy and its complications.
METHODS:	This is a retrospective analysis of case notes of UK service personnel, identified from the UK Joint Theatre Trauma Registry, who sustained traumatic lower-extremity amputation requiring suprainguinal vascular control, following improvised explosive device injury in Afghanistan, between July 2008 and December 2010.
RESULTS:	Fifty-one casualties were identified with a median Injury Severity Score (ISS) of 30. In 10 casualties, control was obtained via an extraperitoneal approach, and in 41, control was obtained via midline laparotomy and intraperitoneal (IP) approach. The most commonly controlled vessel in extraperitoneal control was the external iliac artery, and in IP control, the common iliac artery. Within the 41 patients who had IP control, 13 also required a therapeutic laparotomy, and 9 patients had bilateral injuries at the level of the proximal femur or higher. One patient, who had undergone IP control, experienced an injury to the common iliac vein, which was repaired. There were no other immediate complications recorded, and 39 casualties survived to discharge.
CONCLUSION:	This is the first study to characterize the methods of proximal control in high wartime lower-extremity amputees. Although some casualties will have abdominal injuries that necessitate laparotomy, the majority in our study did not; however, in the critically ill casualty, rapid proximal control is required. Novel methods of temporary hemorrhage control may reduce the need for, and burden of, cavity surgery. (<i>J Trauma Acute Care Surg.</i> 2013;75: S233–S237. Copyright © 2013 by Lippincott Williams & Wilkins)
LEVEL OF EVIDENCE:	Epidemiologic study, level III; prognostic study, level IV.
KEY WORDS:	Hemorrhage; exsanguination; arterial control; combat; trauma.

Traumatic lower-extremity amputation from improvised explosive devices blasts has become the one of the most complex, challenging injuries faced by military surgeons in Afghanistan.¹ Survival is largely dependent on prompt hemorrhage control, which in the setting of distal amputation can usually be accomplished with tourniquets. However, as the amputation level ascends, hemorrhage control becomes more challenging, both in the prehospital and in the hospital setting. The case fatality rate for high transfemoral bilateral amputation exceeds 90%, and junctional bleeding accounts for 20% of overall combat deaths from hemorrhage.^{1,2}

Several devices, pneumatic and mechanical, have been developed for the prehospital control of junctional hemorrhage; in contrast, hospital control has evolved little beyond conventional operative management. In general, the current approach

is to obtain control of the terminal aorta or proximal iliac segments via an intraperitoneal (IP) or an extraperitoneal (EP) approach. The use of laparotomy is further rationalized as there may also be a need to concomitantly manage intra-abdominal hollow- or solid-organ injury.

However, the use of proximal control, the incidence of intra-abdominal injuries, and complications have yet to be characterized in a population with wartime injuries. The aim of the study was evaluate the use of immediate operative control of arterial inflow and its complications.

PATIENTS AND METHODS

This study was approved by the Royal Centre for Defence Medicine Academic Unit. All patients who sustained a traumatic lower-extremity amputation and required suprainguinal vascular control were identified from the UK Joint Theatre Trauma Registry. The search used a combination of body region and surgical procedures coding to identify patients injured between July 2008 and December 2010. The UK Joint Theatre Trauma Registry is a prospective registry recording data on casualties who trigger trauma team activation.³

Data on patient demographics, injury severity and patterns, mechanism of injury, timeline, admission physiology, blood products and surgical procedures were retrieved. Overall injury

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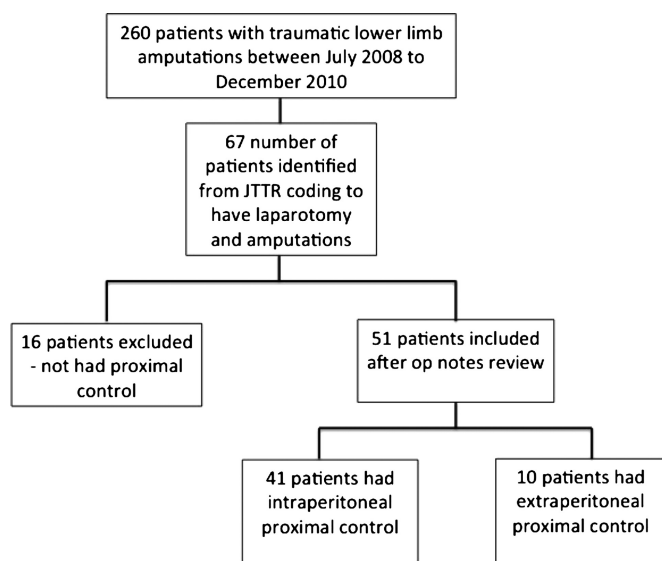


Figure 1. Flow diagram of the cohort selection.

burden was quantified using the Injury Severity Score (ISS) and New Injury Severity Score (NISS).⁴ The Abbreviated Injury Scale (AIS) score was used to classify anatomic injury patterns. A severe injury was defined as an AIS score of 3 or greater.⁵

Patients' charts were reviewed to identify the method of suprainguinal vascular control and complications that arose. In cases where multiple levels of control were used, data on all vessels were collected. EP approach was defined as control of the iliac vessels via midline or Pfannenstiel incisions without breach of the peritoneum. IP approach was defined as control

of vessels via the midline laparotomy incision that opened the peritoneum.

Patients were categorized as survivors or fatalities (30-day mortality), and all statistical analyses were performed using SPSS version 19 software (IBM, New York, NY). *t* tests were used for continuous data, Mann-Whitney rank-sum test was used for ordinal data, and χ^2 test was used for analyzing categorical data.

RESULTS

Between July 2008 and December 2010, 260 patients were identified as having sustained traumatic lower-extremity amputations, of which 51 also required proximal control (Fig. 1). The majority of patients (80.4%) had IP control. Both groups (IP vs. EP) were comparable in age, and all patients were male (Table 1). Mortality was higher in the IP group than in the EP group, although this result was not statistically significant (29.3% vs. 10.0%, $p = 0.210$).

Trauma Scoring and Injury Pattern

The overall median ISS was 30, and NISS was 54. There were no significant differences in ISS, NISS, Revised Trauma Score (RTS), and Trauma Injury Severity Score (TRISS) between the IP and EP groups (Table 1). In the analysis of AIS body region scoring, the IP group had sustained a greater proportion of severe abdominal injury ($p = 0.03$) and upper-extremity trauma ($p = 0.047$) compared with the EP group. All groups had a similar distribution of lower-extremity injuries, reflective of the inclusion criteria.

The distribution of the levels of bilateral lower-extremity amputees in the IP and EP group were similar, with the majority of patients having sustained at least one transfemoral amputation (Table 2). In the IP group, a significantly greater proportion of patients had pelvic fractures compared with EP group (43.9% vs. 10%, $p = 0.047$).

TABLE 1. Baseline Characteristics and Injury Pattern of Patients Requiring Proximal Control

	IP Control	EP Control	<i>p</i>
n	41	10	
Sex, n (%)	41 (100)	10 (100)	—
Age, * y	25 (6)	28 (5)	0.448
Fatalities	12 (29.3)	1 (10.0)	0.210
Trauma scores			
Median ISS (IQR)	30 (14)	30 (12.5)	0.090‡
Median NISS (IQR)	54 (17)	54 (17)	0.777‡
Median RTS (IQR)*	4.09 (2.29)	4.09 (3.20)	0.981‡
Injury pattern			
Head AIS score ≥ 3	3 (7.3)	0 (0)	0.378
Chest AIS score ≥ 3	5 (12.2)	1 (10)	0.847
Abdomen AIS score ≥ 3	14 (34.1)	0 (0)	0.030
Upper-extremity AIS score ≥ 3	8 (19.5)	5 (50)	0.047
Lower-extremity AIS score ≥ 3	41 (100)	10 (100)	—

*Missing data in 17 patients.

‡Mann-Whitney rank-sum test

IP versus EP (χ^2 test, except Mann-Whitney rank-sum test).

Values in parentheses are percentage unless otherwise stated.

IQR, interquartile range.

TABLE 2. Amputation Pattern in Patients Requiring Proximal Control

	IP Control	EP Control	<i>p</i>
n	41	10	
Amputation number			
Single lower extremity	5 (12.2)	1 (10)	0.448
Bilateral lower extremity	28 (68.3)	6 (50)	
Triple	7 (17.1)	4 (40)	
Quadruple	1 (2.4)	0 (0)	
Final lower-extremity amputation configuration			
Bilateral PTF	9 (22)	1 (10)	0.561
Bilateral DTF	9 (22)	3 (30)	
Bilateral BK	2 (4.9)	0 (0)	
Unilateral PTF + other	11 (26.8)	5 (50)	
Unilateral DTF + other	5 (12.2)	0 (0)	
Others	5 (12.2)	1 (10)	

Values in parentheses are percentage unless otherwise stated.

Others include single PTF, single DTF, single TK, single BK, TK/BK. IP versus EP (χ^2 test).

BK, below the knee; DTF, distal transfemoral; PTF, proximal transfemoral; TK, through the knee.

TABLE 3. Breakdown of Vessel Control

	IP Control	EP Control	<i>p</i>
n	41	10	
Laterality			
Right iliac segment only	5 (12.2)	2 (20)	0.155
Left iliac segment only	3 (7.3)	3 (30)	
Bilateral iliac segments	30 (73.2)	5 (50)	
Aorta control only	3 (7.3)	0 (0)	
Named vessels			
Aorta controlled	8	—	
In isolated	3 (37.5)	—	
No CIA control	17 (41.5)	7 (70)	0.026
Right CIA	4 (9.8)	0 (0)	
Left CIA	1 (2.4)	2 (20)	
Bilateral CIA	19 (46.3)	1 (10)	
No IIA control	30 (73.2)	8 (80)	0.012
Right IIA	0 (0)	2 (20)	
Left IIA	3 (7.3)	0 (0)	
Bilateral IIA	8 (19.5)	0 (0)	
No EIA control	31 (75.6)	3 (30)	0.002
Right EIA	1 (2.4)	3 (30)	
Left EIA	1 (2.4)	2 (20)	
Bilateral EIA	8 (19.5)	2 (20)	

Values in parentheses are percentages. IP versus EP (χ^2 test).

TABLE 4. Abdominal Surgery: Indications and Interventions

	Laparotomy
n	41
Indications	
Proximal control	19 (46.3)
Hemodynamic instability	12 (29.3)
Clinical suspicion	10 (24.4)
Imaging directed	0 (0)
Interventions	
Proximal control	40
Solid organ	4
Hollow organ	13
Vascular repair	1
Category	
Proximal control, in isolation	23 (56.1)
Proximal control, plus intervention	17 (41.5)
No proximal control, intervention only	0 (0)
Nontherapeutic laparotomy	1 (2.4)

Values in parentheses are percentage unless otherwise stated.

who had bilateral CIA control, one patient subsequently had bilateral internal iliac artery (IIA) control. In the EP group, one patient (10%) had bilateral CIA control. The control of the IIA was used more commonly via the IP approach compared with EP ($p = 0.012$). External iliac artery (EIA) was the most common vessel controlled via the EP approach (Table 3, Fig. 2).

Type of Vascular Control

Eight patients initially required aortic control, which was released once more distal control had been established in five cases. In the IP group ($n = 41$), the majority of patients (73.2%) had bilateral control along the length of their iliac segments and unilateral control in 19.6%. Right-sided iliac segment control was more common in IP group (12.5% vs. 7.3%). In the EP group ($n = 10$), half of the patients had bilateral control of iliac segments, followed by 30% that had left-sided control. There is no statistical significance observed in the various lateralities (Table 3, Fig. 2).

The common iliac artery (CIA) was the most common vessel controlled in the IP group; among the 19 patients (46.3%)

Indications of Abdominal Surgery

In the cohort of patients who had IP control, the indication for laparotomy was mainly for proximal control (46.3%) followed by hemodynamic instability (29.3%) and clinical suspicion of intra-abdominal injuries (24.6%). Hollow-organ intervention was performed in 13 of the laparotomies, mainly for formation of colostomy (Table 4). Solid-organ hemorrhage control maneuvers such as liver packing or splenectomy was performed in four patients in this cohort. More than half of the patients only had proximal control from the laparotomy; 41.5% of the patients had proximal control and other intra-abdominal intervention (Table 4).

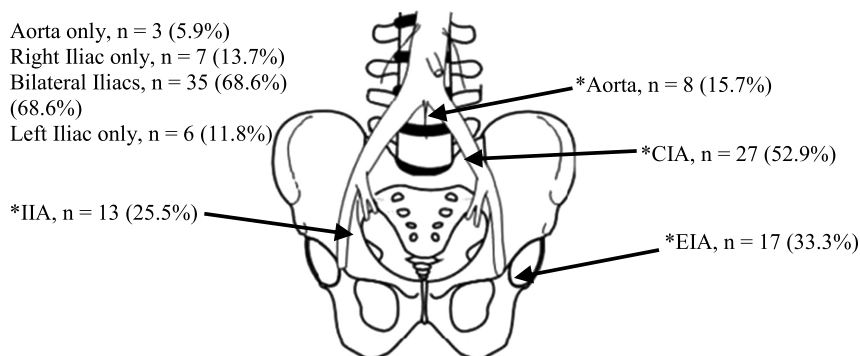


Figure 2. Line drawing of the pelvic vasculature with relative proportions of the regions used for control. Values in parentheses are percentages. *Multiple vessels allowed for. Reproduced from Stannard et al.¹⁶ with permission from Wolters Kluwer Health.

One trauma laparotomy with negative finding was performed in the IP group, with initially suspected abdominal injury; hence, laparotomy, which showed no intraoperative findings; however, the patient proceeded to have IP proximal vascular control for superficial femoral artery and vein through-and-through injury.

Three patients underwent a laparotomy in the EP group; one patient had EP vascular control followed by computed tomography, which showed free air, and the patient proceeded to undergo laparotomy and had negative findings. The remaining two patients in this group underwent formation of colostomy.

Complications

One patient, who had undergone IP control, experienced an injury to the common iliac vein, which was repaired. There were no other immediate complications reported.

DISCUSSION

This study reports a consecutive series of 51 patients with traumatic lower-extremity amputation in wartime who required suprainguinal inflow control. The majority of patients (80.4%) had their peritoneum explored through a midline laparotomy, and more than half of the patients (56.1%) undergoing laparotomy required no other abdominal intervention.

Traumatic amputation in wartime carries a significant burden of mortality: 40.8% of patients die before hospital admission, with an in-hospital mortality of 16.0%.¹ Hemorrhage constitutes the leading cause of death—bilateral proximal hind-quarter amputations are almost universally fatal, decreasing to a case fatality rate of 18.0% for unilateral below-knee amputations.¹

The mortality from isolated extremity injury has decreased, largely attributed to the introduction of tourniquets.^{6,7} However, iliofemoral junctional and pelvic bleeding remains highly lethal^{2,8} and challenging to manage.^{9,10} The devastating soft tissue injury associated with perineal blast injury often results in the disruption of vessels in hard-to-reach places. For example, gluteal artery hemorrhage is difficult to control by direct means, such as gauze packing; thus, proximal control of the internal iliac becomes a key hemostatic maneuver. There is a higher mortality in the IP group, compared with the EP, although this does not achieve statistical significance, likely owing to a lack of power within the study.

The war in Afghanistan has become characterized by the use of improvised explosive devices, which are associated with high, often bilateral, lower-extremity amputations, as well as pelvic and genital injuries. This constellation has been termed the *dismounted complex blast injury (DCBI)* because it is generally sustained by military personnel on foot.¹¹ Care in-hospital consists of concomitant resuscitation and hemorrhage control,^{9,10} often necessitating general and orthopedic surgeons working synchronously, as well as massive transfusion and hemostatic resuscitation, administered by the anesthetic team. Most of the vascular injuries in our cohort were blast related, with disruption of lower-extremity vasculature, where the use of proximal control is used to control bleeding and facilitate amputation.

The current study demonstrates that proximal control is felt necessary in one in five patients who sustain a traumatic lower-extremity amputation and seems to be associated with few complications. A greater number of patients had proximal control

achieved by an IP route, which may reflect the rapidity with which infraaortic control can be achieved. Furthermore, more than half of these patients do not require any other abdominal intervention, which asks the question if control can be achieved by less invasive means.

Resuscitative endovascular balloon occlusion of the aorta is a recently described endovascular concept where a compliant balloon is placed in the aorta to support central pressure while also providing inflow control.¹² Infraarenal balloon occlusion has been demonstrated to improve survival from pelvic hemorrhage in both animal and clinical studies.^{13,14} Such an approach may become more feasible as endovascular capabilities become more common place in deployed operations.¹⁵

The current study has a number of limitations that are important to recognize. The retrospective nature of this study's methodology may mean that not all eligible patients were identified and that use of proximal has been underestimated. Furthermore, we are unable to comment on whether suprainguinal vascular control was clinically necessary or not. We are also unable to collect reliable and consistent data on the time of control required and its effectiveness. It is also well known that documentation of complications is poor, so despite a comprehensive chart review, not all morbidity may have been captured.

Despite these limitations, this study provides insight into the use of proximal control in wartime. One in five patients with a traumatic amputation requires laparotomy for proximal control, which seems to be associated with little morbidity. However, more than half of patients require no other intra-abdominal intervention, suggesting that less invasive techniques of proximal control may have a role in the future. Further prospective study is required to determine the need and effectiveness of proximal control, coupled with the exploration of novel prehospital and in-hospital hemorrhage control techniques.

AUTHORSHIP

H.P. contributed to the data collection, analysis, and writing. J.J.M. contributed to the study concept, data collection, analysis, interpretation, and writing. J.C.C. contributed to the study concept, analysis, interpretation, and writing. M.J.M. contributed to the study concept, analysis, interpretation, and writing. J.O.J. contributed to the study concept, analysis, interpretation, writing, and leadership. We are grateful to the staff at the UK Joint Theatre Trauma Registry, Royal Centre for Defence, Birmingham, United Kingdom, for assisting with the identification of patients. We also thank Mr. Paul Bontiff and his staff for assisting with access to patient records at MoD Shoeburyness, Essex, United Kingdom.

DISCLOSURE

The authors declare no conflicts of interest.

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